HALEY ALDRICH

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TECHNICAL MEMORANDUM

10 January 2020
File No. 129687-012

TO: Florence Copper Inc.
Richard Tremblay, Vice President Operations

FROM: Haley & Aldrich, Inc.
Mark Nicholls, R.G.

SUBJECT: Summary of the Cause for Exceedance of the Bulk Electrical Conductivity Alert Level at the PTF Wellfield

Registered Geologist
Certificate No.
Mark D. Nicholls
Date Signed 1/10/20
Arizona, U.S.A.
Exp. 9/30/21

Introduction

Florence Copper Inc. (Florence Copper) operates the Production Test Facility (PTF) wellfield for the purpose of demonstrating the feasibility of In-Situ Copper Recovery (ISCR) methods to recover copper from the Poston Butte copper deposit in Florence, Arizona. The PTF is authorized by Temporary Aquifer Protection Permit (APP) No. P-106360 and Underground Injection Control (UIC) Permit No. R9UIC-AZ3-FY11-1. Section 2.2.4 of the APP requires that Florence Copper measure bulk electrical conductivity (bulk EC) to confirm hydraulic control. Section 2.5.9 of the APP sets forth the requirements for establishing ambient bulk EC values, and for calculating an appropriate bulk EC alert level (AL). Section 2.6.2.7 of the APP sets forth requirements associated with a confirmed exceedance of the bulk EC AL.

This Technical Memorandum describes confirmed exceedances of the bulk EC AL on three monitoring horizons at three PTF observation wells beginning on 21 November 2019. In accordance with Section 2.6.2.7(4) of the APP, this Technical Memorandum describes the cause, impact, mitigation of the exceedances, and describes any errors in measurement, data analysis, and statistical evaluation of the bulk EC data.

Bulk EC Monitoring Description

In accordance with requirements of the APP, Florence Copper has been collecting bulk EC data weekly, and comparing those data to the ALs established based on ambient bulk EC monitoring conducted prior to the start of PTF operations. The bulk EC compliance monitoring system includes three bulk EC sensors, installed on each of the seven observation wells (identified as O-01 through O-07) at the edge of the PTF wellfield, resulting in a total of 28 sensors. The location of the observation wells relative to the PTF wellfield is shown on Figure 1. The sensors are configured to create four horizontal monitoring horizons with a vertical separation of 20 feet between each horizon. The monitoring horizons are numbered 1 through 4, with horizon 1 being the highest in elevation and horizon 4 being the lowest. Horizon 4 is located in the middle of the 40-foot thick exclusion zone and is not used for compliance monitoring, but is used for operational monitoring to allow Florence Copper to adjust operations prior to an excursion reaching the compliance bulk EC sensors placed 20 feet above at the contact between bedrock and the lower basin fill unit (LBFU). Bulk EC monitoring horizon 3 is at the bedrock LBFU contact, monitoring horizon 2 is 20 feet above the contact within the LBFU, and monitoring horizon 1 is 40 feet above the contact also within the LBFU.

Monitoring is conducted by serially energizing each of the individual sensors on each monitoring horizon and recording the relative signal at each of the other sensors on that monitoring horizon. The resulting measurement reflects the combined conductivity of all material and fluid between the energized sensor and the receiving sensor. The sending and receiving sensors are referred to as "sensor pairs" throughout the remainder of this document. The value measured between each sensor pair is referred to as "bulk conductivity" because it reflects the combined relative conductivity of the formation material, groundwater, well casings, annular materials, and injected fluid (if present) between the sensors. Bulk EC values are reported in terms of resistivity, which is the inverse of conductivity, and the reporting units are ohm-meters (Ω-m).

The bulk EC AL values are a lower limit, consequently a bulk EC value that declines below the AL is characterized as an exceedance. Because the injected fluid has significantly higher conductivity than native groundwater, a vertical excursion of injected fluid will result in a localized increase in bulk EC detected at multiple sensor pairs. Florence Copper submitted a proposal in August 2018, that included a description of the method for establishing the bulk EC ALs and included discussion of method sensitivity and factors that may affect bulk EC values.

Based on the configuration of the bulk EC monitoring system, a hypothetical vertical excursion of injected fluid would progress upward from a localized detection of decreased resistivity at the lowest monitoring horizons. Because the ISCR fluid is very conductive, an excursion of fluid from the injection zone would abruptly change the measured bulk EC value in a very short time frame, in contrast to the gradual changes that would be expected from environmental changes or sensor drift. The localized occurrences would expand horizontally on the lower horizons as new detections occurred on the upper horizons. A vertical excursion would thus be detected first on monitoring horizon 4, then on monitoring horizons 3, 2, and 1, in that order. A vertical excursion of injected fluid would be accompanied by the following sequential observations:

1. Localized detection of reduced resistivity at a localized area on monitoring horizon 4.
2. Localized detection of reduced resistivity at a localized area on monitoring horizon 3 and expanding localized detection of reduced resistivity on horizon 4.
3. Localized detection of reduced resistivity at a localized area on monitoring horizon 2 and expanding localized detection of reduced resistivity on horizons 3 and 4.
4. Localized detection of reduced resistivity at a localized area on monitoring horizon 1 and expanding localized detection of reduced resistivity on horizons 2, 3, and 4.

Bulk EC monitoring is an effective means to monitor for vertical migration of injected fluid above the exclusion zone but relies on the assumption that migration of injected fluid is the only changing condition within the wellfield, and that all other factors affecting bulk EC remain unchanged during PTF operations. Consequently, changes in other conditions at the PTF wellfield that affect bulk EC have the potential to depress the resistivity values resulting in an apparent bulk EC exceedance.

Confirmed Bulk EC Exceedance

Bulk EC data collected on 21 November 2019, reflected a downward shift in resistivity values measured between all sensor pairs on all monitoring horizons. The downward shift in resistivity values resulted in exceedance of the AL at five sensor pairs located on three monitoring horizons. The exceedances were first observed in bulk EC data collected on 21 November 2019, which were reported to Florence Copper on 2 December 2019, following completion of statistical analysis of the raw data. The exceedances were confirmed by bulk EC measurements made on 26 November and 3, 4, and 5 December 2019.

Statistical analysis of the bulk electrical conductivity data collected through 5 December were completed on 10 December 2019. Florence Copper was notified that the exceedances were confirmed on 11 December 2019. The observed changes in bulk EC values measured on 21 November reflect a relative change in bulk EC of between 1 and 8 percent relative to previous measurements. The electrode pairs that indicated exceedance of the bulk EC ALs experienced changes of 2 to 3 percent and exhibited the lowest baseline bulk EC values. The observed exceedances and confirmation measurements are summarized in Table 1.

Table 1. Summary of Observed Bulk EC Exceedances and Confirmation Values

Horizon and Electrode Pair*	AL (Ω-m)	11/21 Results Ω-m)	11/26 Results (Ω-m)	12/3 Results (Ω-m)	12/4 Results (Ω-m)	12/5 Results (Ω-m)	12/11 Results (Ω-m)
Horizon 1, between wells O-05 and O-06	9.93	9.77	9.77	9.72	9.72	9.71	9.77
Horizon 1, between wells O-06 and O-07	9.93	9.85	9.84	9.82	9.79	9.81	9.85
Horizon 2, between wells O-05 to O-06	10.12	10.00	9.99	9.96	9.94	9.94	9.99
Horizon 3, between wells O-05 to O-06	10.33	10.28	10.28	10.23	10.22	10.21	10.26
Horizon 3, between wells O-05 to O-07	10.33	10.20	10.20	10.13	10.13	10.10	10.18
*Horizon 3 is the deepest compliance monitoring horizon and is located at the bedrock lower basin fill unit contact and is the closest to the injection zone. Horizon 1 is the shallowest monitoring horizon and is furthest from the injection zone.							

Once the potential exceedances were confirmed, Haley & Aldrich, Inc. (Haley & Aldrich) conducted an evaluation of the wellfield conditions, operations, meteorological changes, and other environmental changes to identify the cause of the exceedances in accordance with Section 2.6.2.7 of APP No. P-106360.

Comparative Bulk EC Values from PTF Operational Monitoring

In addition to the compliance bulk EC monitoring conducted at horizons 1 through 3, Florence Copper is conducting operational bulk EC monitoring at horizon 4 and at greater depth within the injection zone. The operational monitoring provides for comparison of the measured bulk EC values measured for compliance monitoring with values measured in areas where injected solution is known to be in contact with bedrock, and at locations between the injection zone and the compliance monitoring points.

OPERATIONAL MONITORING AT HORIZON 4

As described above, APP No. P-106360 establishes bulk EC AL values for monitoring horizons 1 through 3. Horizon 4 is located 20 feet below horizon 3 in the middle of the 40-foot thick exclusion zone and does not have an AL. Monitoring horizon 4 is used for operational monitoring to allow Florence Copper to identify changing conditions prior to a potential vertical excursion reaching the LBFU. The monitoring system is configured such that a vertical excursion would have to pass horizon 4 before reaching the other horizons. Consequently, horizon 4 would thus be expected to have a lower resistivity value than that observed on the higher horizons in the event of a vertical excursion.

Bulk EC data collected at monitoring horizon 4, at the time the exceedances were identified and confirmed on horizons 3, 2, and 1, showed higher resistivity values than the overlying horizons and a similar magnitude of change. This fact indicates that there is no notable differential between the changes observed on horizon 4, relative to the changes observed on horizons 3, 2, and 1, and that there is no residual evidence of upward migration of injected fluid. Table 2 lists the bulk EC values measured on horizon 4 at observation wells O-05, O-06, and O-07 during the monitoring events which detected and confirmed the AL exceedances on horizons 1, 2, and 3.

Table 2. Summary of Observed Bulk EC Values on Horizon 4 During the Period Exceedances Were Observed and Confirmed on Horizons 3, 2, and 1

Horizon and Electrode Pair*	AL (Ω-m)	11/21 Results Ω-m)	11/26 Results (Ω-m)	12/3 Results (Ω-m)	12/4 Results (Ω-m)	12/5 Results (Ω-m)	12/11 Results (Ω-m)
Horizon 4, between wells O-05 and O-06	N/A	10.62	10.61	10.57	10.56	10.53	10.60
Horizon 4, between wells O-05 and O-07	N/A	10.47	10.47	10.40	10.39	10.38	10.46
*Horizon 3 is the deepest compliance monitoring horizon and is located at the bedrock lower basin fill unit contact. Horizon 4 is located within the exclusion zone, is monitored for operational purposes, and does not have an alert level.							

OPERATIONAL MONITORING IN THE INJECTION ZONE

In addition to the bulk EC monitoring system constructed for the purpose of compliance and operational monitoring described above, Florence Copper has constructed an additional bulk EC operational monitoring system within the injection zone to facilitate analysis of fluid flow between the injection and recovery wells. Operational monitoring within the injection zone began prior to the commencement of injection and has continued throughout 2019. This operational monitoring within the injection zone provides an opportunity to compare bulk EC values, where injected solution is known to be in contact with bedrock, to the observed bulk EC values in the overlying monitoring horizons 1 through 4. The uppermost operational bulk EC monitoring within the injection zone is conducted at a depth of 168 feet below monitoring horizon 4.

Operational monitoring within the injection zone yields bulk EC values that are consistently below 3 Ω-m throughout the injection zone, and are in the range of 2 Ω-m at a depth of 168 feet below monitoring horizon 4. If a vertical excursion were moving upward from the injection zone through monitoring horizon 4, it is anticipated that bulk EC measurements at horizon 4 would reflect the low bulk EC values observed in the injection zone. However, the bulk EC values measured at horizon 4 remain some of the highest observed in the monitoring network, indicating that a vertical excursion has not occurred.

Bulk EC AL Exceedance Cause, Impact, and Mitigation

OBSERVED BULK EC SENSITIVITY TO PRECIPITATION DURING THE AMBIENT MONITORING PERIOD

Bulk EC monitoring is a highly sensitive method used for detecting changes in the conductivity of the formation materials above the PTF injection zone. As described in the August 2018 AL proposal, this method of monitoring is sensitive to environmental changes in addition to those generated by migration of injected fluid. The AL proposal described potential spatial variability related to lithology, moisture content, fluid temperature, and electrolyte content, and temporal variability related to seasonal changes, meteorological events, and sensor drift.

Baseline bulk EC data was collected at the PTF wellfield between 24 May and 3 August 2018. The baseline bulk EC data showed sensitivity to precipitation events, but relatively low variability (generally less than 1 Ω-m). The variability of the baseline dataset, sensitivity to environmental changes, and method for calculation of the ALs are described in the August 2018 AL proposal.

Section 4.1.2 of the August 2018 AL proposal describes the effects on the baseline dataset of precipitation events occurring on 16 through 17 June and 29 through 31 July 2018. Both of these events precede notable declines in the bulk EC values compared to values measured before the precipitation events. The 16 through 17 June 2018 precipitation event produced approximately 1 inch of rain and preceded a decline in bulk EC values of up to 0.77 Ω-m and 5.1 percent compared to pre-event values. The 29 through 31 July 2018 precipitation event produced approximately 0.7 inch of rain and preceded a decline in bulk EC values of up to 1.3 Ω-m and 4.9 percent compared to pre-event values.

The August 2018 AL proposal noted that rainfall added soil moisture at the surface which would lower temperatures in the surficial infrastructure used to collect the data. Temperature fluctuations change the resistivity of the cables used to transmit the signals to and from the wells from the resistivity instrument as well as the cables at the surface used as reference electrodes. It is also important to note that the ambient bulk EC data were collected over a relatively short period of time in the summer of 2018, and consequently do not fully characterize potential seasonal variability arising from reduced ambient air temperatures and reduced evaporation of residual soil moisture. These types of seasonal changes have the potential to affect the surficial components of the bulk EC monitoring system, the grounding network, and the reference electrodes used to process the raw bulk EC data. The ambient bulk EC data, observed temporal variability during the ambient monitoring period, and correlation to precipitation events are described in the August 2018 AL proposal.

CORRELATION OF OBSERVED CHANGES IN BULK EC AND PRECIPITATION EVENTS

Comparison of bulk EC data, collected during the operational monitoring period, to precipitation data show correlation between precipitation events and observed declines in bulk EC values. Figures 2 through 8 are time series plots of the average measured bulk EC values at each of the four monitoring horizons at each of the seven observation wells throughout the operational monitoring period beginning on 21 September 2018 and extending through 23 December 2019. The bulk EC data are plotted together with precipitation data from a weather station (NOAA Station ID US1AZPN0075) located approximately 3.3 miles northeast of the PTF wellfield.

Figures 2 through 8 show that decline in bulk EC values occurred on all four monitoring horizons following significant rain events throughout 2019, and that successive smaller rain events have a cumulative residual effect on bulk EC values. During dry periods between rain events, as residual soil moisture evaporates and soil temperatures rise, bulk EC values appear to stabilize or trend upwards. Figures 2 through 8 also show the following notable characteristics:

1. A downward shift of bulk EC values has occurred at a similar magnitude on every monitoring horizon (horizons 1 through 4) following significant precipitation events and successive smaller precipitation events. Review of the underlying data show that a similar magnitude downward shift occurs on every sensor pair in the monitoring system on every monitoring horizon. This type of shift indicates that changing conditions affected the entire monitoring system equally, and that the change is not related to upward migration of injected fluid, but rather with a change in the baseline conditions in the grounding network or reference electrodes used to process the individual bulk EC measurements.
2. The downward shift in bulk EC values detected on 21 November 2019 was preceded by two precipitation events (14 and 20 November 2019) that each produced greater than 1 inch of precipitation. Similar declines in bulk EC values were preceded by precipitation events on 25 September 2019, cumulative precipitation events between 31 January through 14 February 2019, and cumulative precipitation events between 5 and 19 October 2018. Similar to the 21 November precipitation event, each of the earlier precipitation events preceded system wide decline in bulk EC values.
3. The observed changes in bulk EC values are not spatially localized within the PTF wellfield, suggesting that there is not a localized pathway for vertical migration of solution.
4. The observed change in bulk EC values did not progress from the lowest level sensors on monitoring horizon 4, upward to horizons 3, 2, and 1 as would be expected if a vertical excursion of injected fluid had occurred. Rather, the change occurred at a similar magnitude, at the same time, at all sensor pairs on all monitoring horizons.

5. The resistivity values measured at monitoring horizon 4 remain higher than those measured in horizons 3, 2, and 1. This indicates that injected solution has not migrated upward through horizon 4 to reach horizons 3, 2, and 1. Had injected solution migrated vertically upward, it is anticipated that the lowest monitoring horizon, horizon 4, would have a lower resistivity than the overlying horizons instead of the higher values measured at horizon 4.
6. Additional rain events occurred following the initial exceedance detection on 21 November and during the period when confirmation monitoring was conducted.

It is important to note that precipitation falling on the surface at the PTF wellfield is not infiltrating to the bulk EC sensors located in the well bores to cause a decrease in bulk EC values. Rather, precipitation falling on the surface is affecting the equipment, grounding network, and reference electrode system located at ground surface which are used to collect the bulk EC data for processing the raw data.

Based on the data and information presented above, the bulk EC exceedances detected on 21 November 2019, and confirmed 26 November through 5 December 2019, were caused by the residual effects of successive precipitation events occurring prior to 21 November, which increased cumulative ambient soil moisture, decreased soil temperature, and resulted in other environmental changes affecting the surficial components of the bulk EC monitoring network, associated grounding network, and reference electrodes. These environmental changes had a systemwide affect, reducing all measured bulk EC values at all electrode pairs on all monitoring horizons by a similar magnitude, and resulted in the electrode pairs with the lowest ambient bulk EC values exceeding the horizon AL values.

Environmental Impacts

The observed bulk EC exceedances described above are the result of ambient environmental changes at ground surface and are not the result of a vertical excursion of injected fluid. No adverse environmental impacts are known to have occurred as a result of the observed bulk EC exceedances.

Mitigation of Environmental Impacts

No adverse environmental impacts are known to have occurred as a result of the observed bulk EC exceedances. Consequently, no mitigation of environmental impacts is required.

In accordance with Section 2.6.2.7 of the APP Permit, Florence Copper has increased the bulk EC monitoring frequency to three times per week. Florence Copper continues to actively monitor wellfield operational conditions and to actively maintain hydraulic control.

The August 2018 AL proposal included discussion of potential change in ambient bulk EC conditions arising from seasonal changes, instrument drift and other factors, and identified the potential need to revise the bulk EC ALs based on these factors. Haley & Aldrich has commenced statistical analysis of the bulk EC data for the purpose of re-calculating AL values to be included in a proposal for revised AL values in an application to amend APP No. P-106360.

Potential Errors in Measurement, Data Analysis, and Statistical Evaluation

Haley & Aldrich has reviewed measurement, data analysis, and statistical analyses of the bulk EC data and has concluded that the observed bulk EC exceedances did not result from errors in measurement, data analysis, or statistical analysis.

Conclusion

The bulk EC exceedances detected on 21 November 2019, and confirmed 26 November through 5 December 2019, are the result of natural changes in ambient environmental conditions at the PTF wellfield. The ambient environmental changes which resulted in the bulk EC exceedances were referenced in the August 2018 AL proposal describing the ambient bulk EC dataset, ambient data variability, and proposed method for AL calculation. The AL proposal specifically identified the sensitivity of the bulk EC monitoring method to precipitation events and provided direct examples of precipitation events that resulted in similar changes to ambient bulk EC values.

The confirmed bulk EC exceedances were caused by the cumulative effects of precipitation events occurring prior to 21 November 2019 which resulted in an increase of ambient soil moisture, decreased soil temperature, and resulted in other environmental changes affecting the surficial components of the bulk EC monitoring network, associated grounding network, and reference electrodes.

The exceedances are not the result of measurement error, data analysis error, or error in statistical analyses. The confirmed bulk EC exceedances are not the result of vertical excursion of injected fluid, no impacts to the environment are known to exist as a result of the bulk EC exceedances, and no environmental mitigation is required.

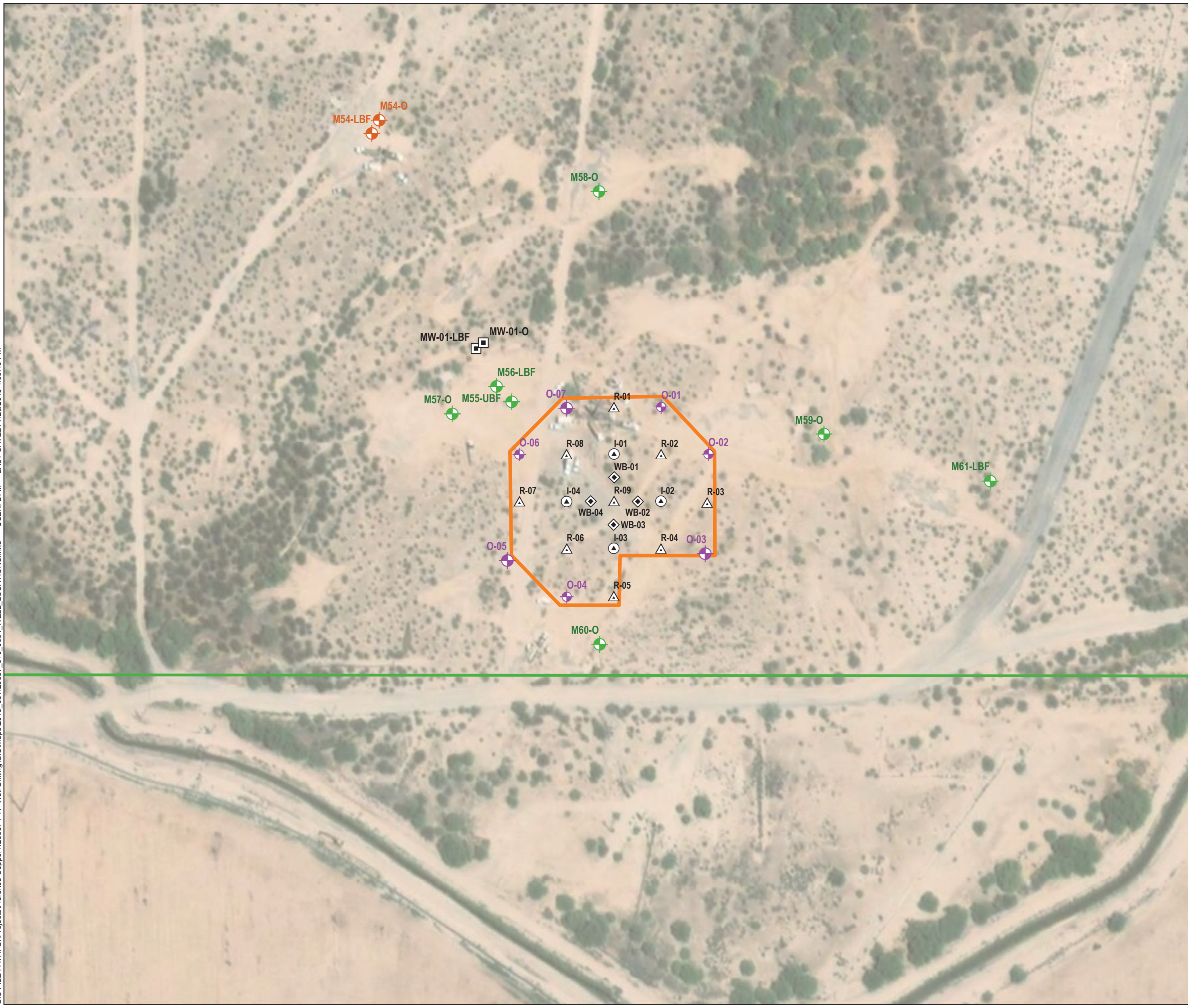
Haley & Aldrich has commenced statistical analysis of the bulk EC data for the purpose of re-calculating AL values and Florence Copper will propose revised AL values in an application to amend APP No. P-106360.

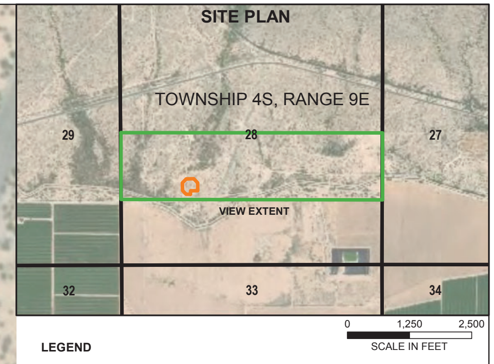
Please contact Mark Nicholls with any questions you may have regarding the content of this Technical Memorandum.

Enclosures:

- Figure 1 – PTF Wellfield Configuration
- Figure 2 – Observation Well O-01: All Horizons
- Figure 3 – Observation Well O-02: All Horizons
- Figure 4 – Observation Well O-03: All Horizons
- Figure 5 – Observation Well O-04: All Horizons
- Figure 6 – Observation Well O-05: All Horizons
- Figure 7 – Observation Well O-06: All Horizons
- Figure 8 – Observation Well O-07: All Horizons

FIGURES





LEGEND

OBSERVATION WELL
SUPPLEMENTAL MONITORING WELL
POINT-OF-COMPLIANCE WELL

PTF WELLS

INJECTION
RECOVERY
WESTBAY WELL
OPERATIONAL MONITORING
PTF WELL FIELD
STATE LAND LEASE

NOTES

1. ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE.
2. AERIAL IMAGERY SOURCE: ESRI

N

0 150 300
SCALE IN FEET

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FLORENCE COPPER PROJECT
FLORENCE, ARIZONA

PTF WELLFIELD CONFIGURATION

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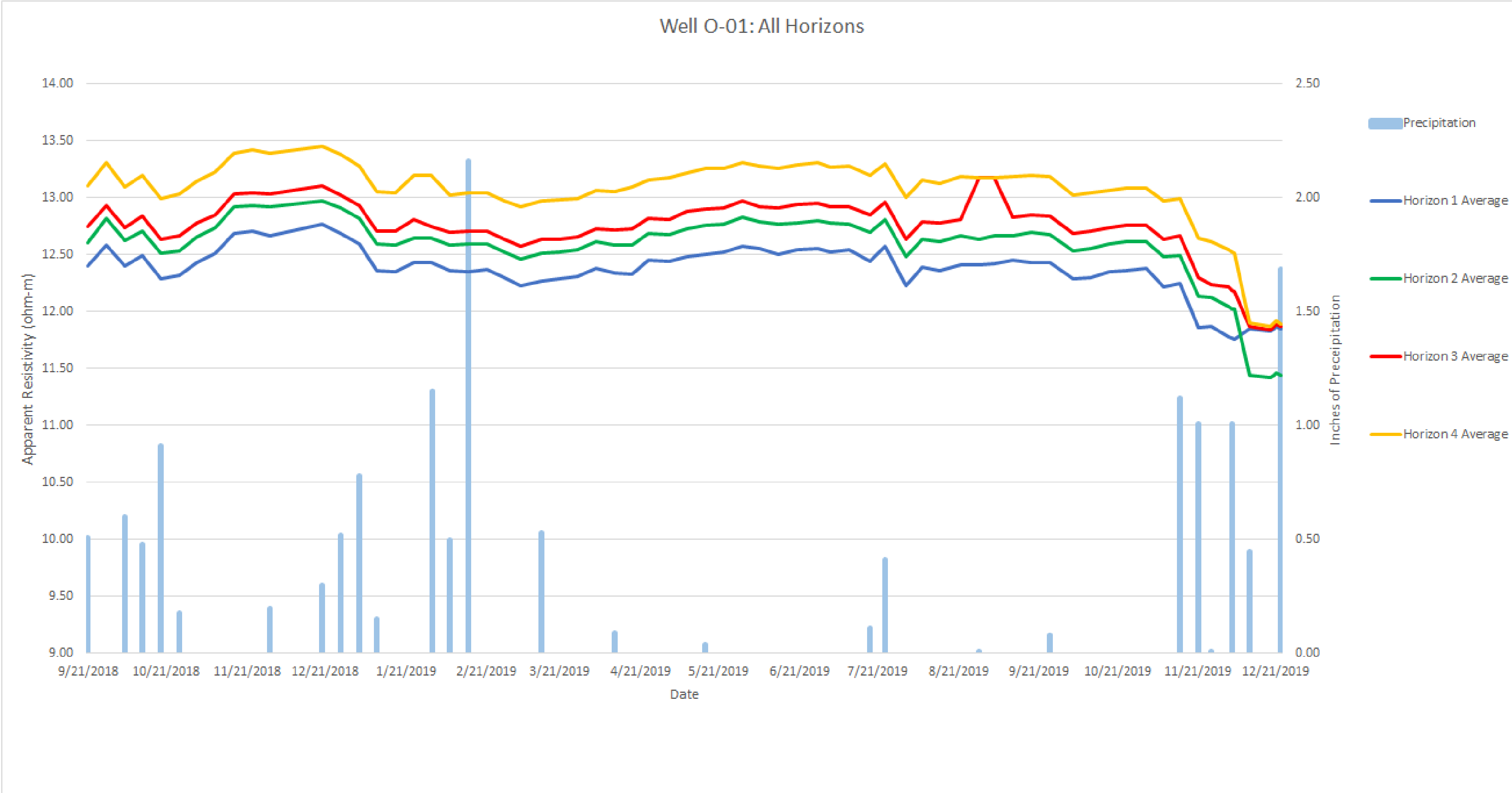
FIGURE 1

GIS FILE PATH: G:\Projects\Florence Copper\129687 PTF Well Drilling\GIS\Maps\2018_08\129687_010_0001_WELL_LOCATIONS.mxd — USER: DFM — LAST SAVED: 7/25/2018 4:09:40 PM



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OBSERVATION WELL O-01:
ALL HORIZONS

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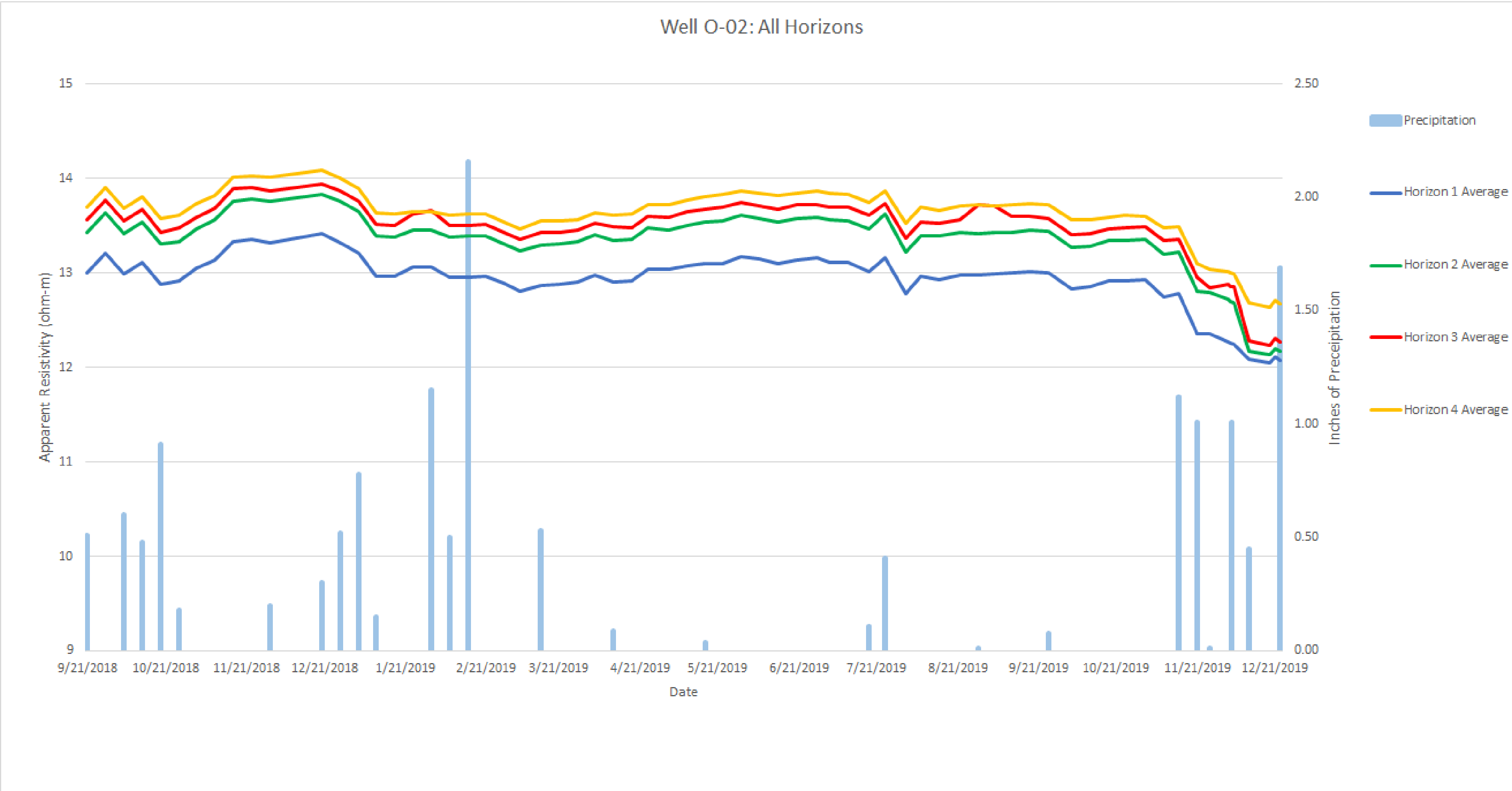
FIGURE 2



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OBSERVATION WELL O-02:
ALL HORIZONS

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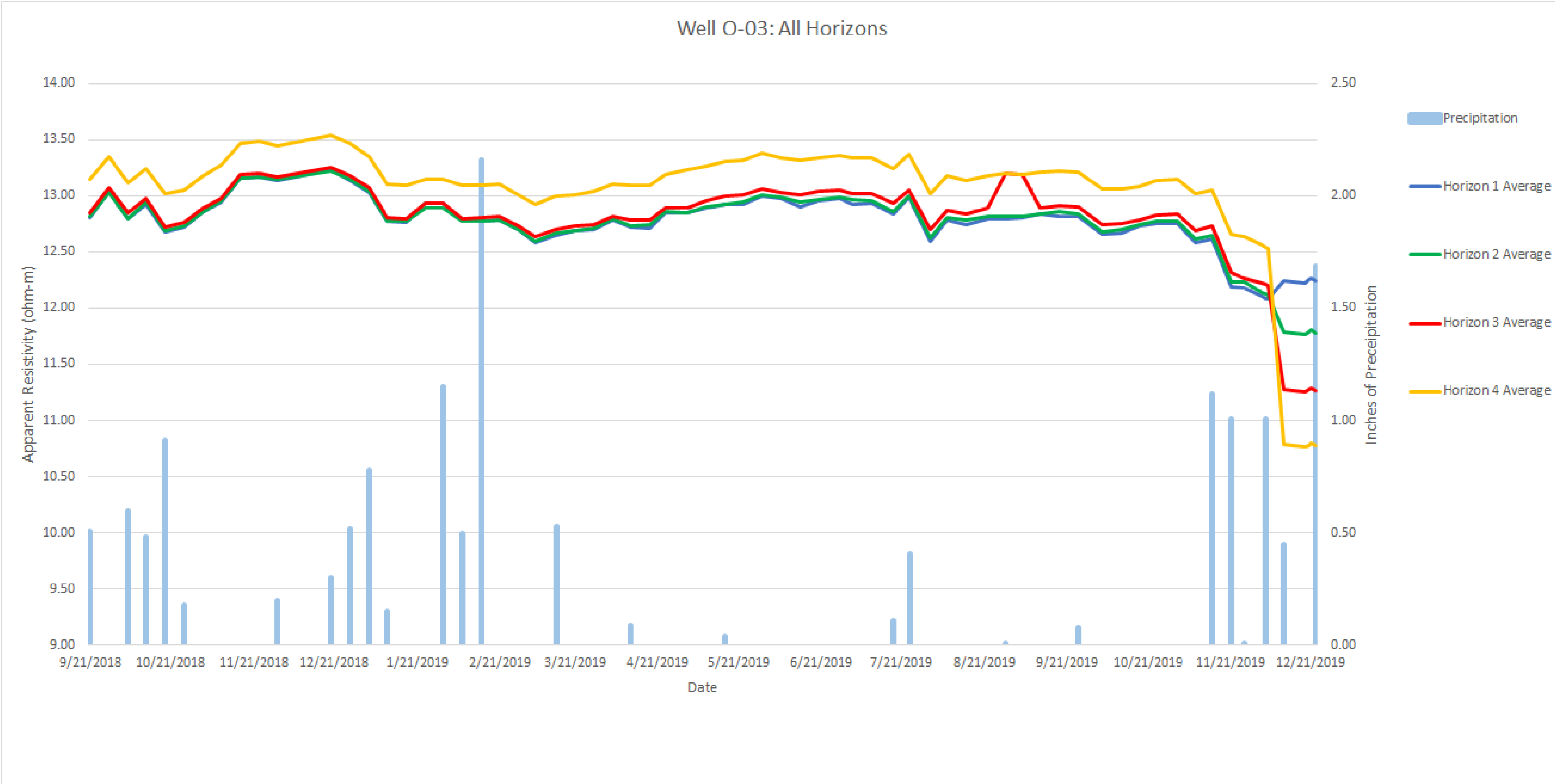
FIGURE 3



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OBSERVATION WELL O-03:
ALL HORIZONS

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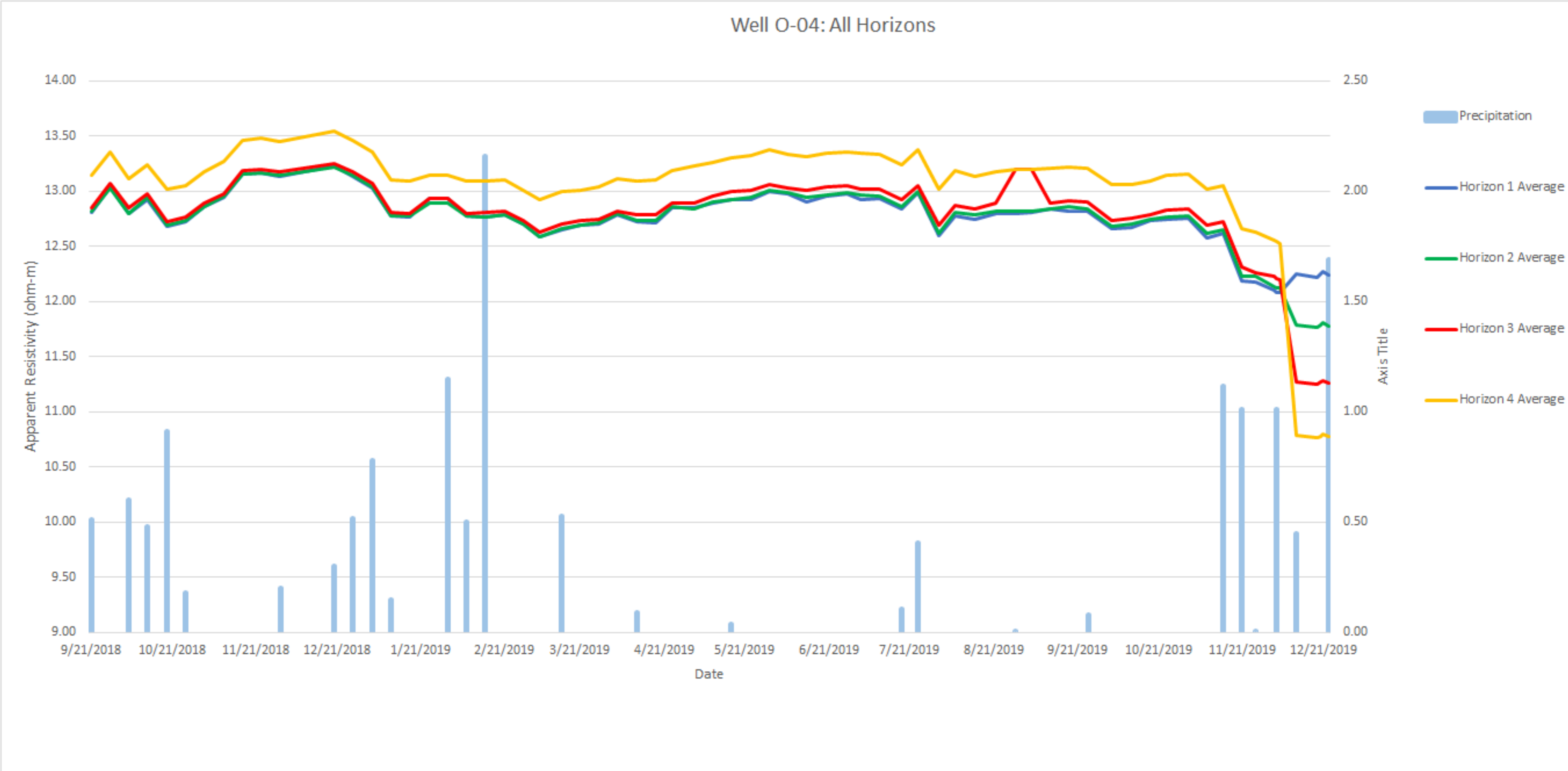
FIGURE 4



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OBSERVATION WELL O-04:
ALL HORIZONS

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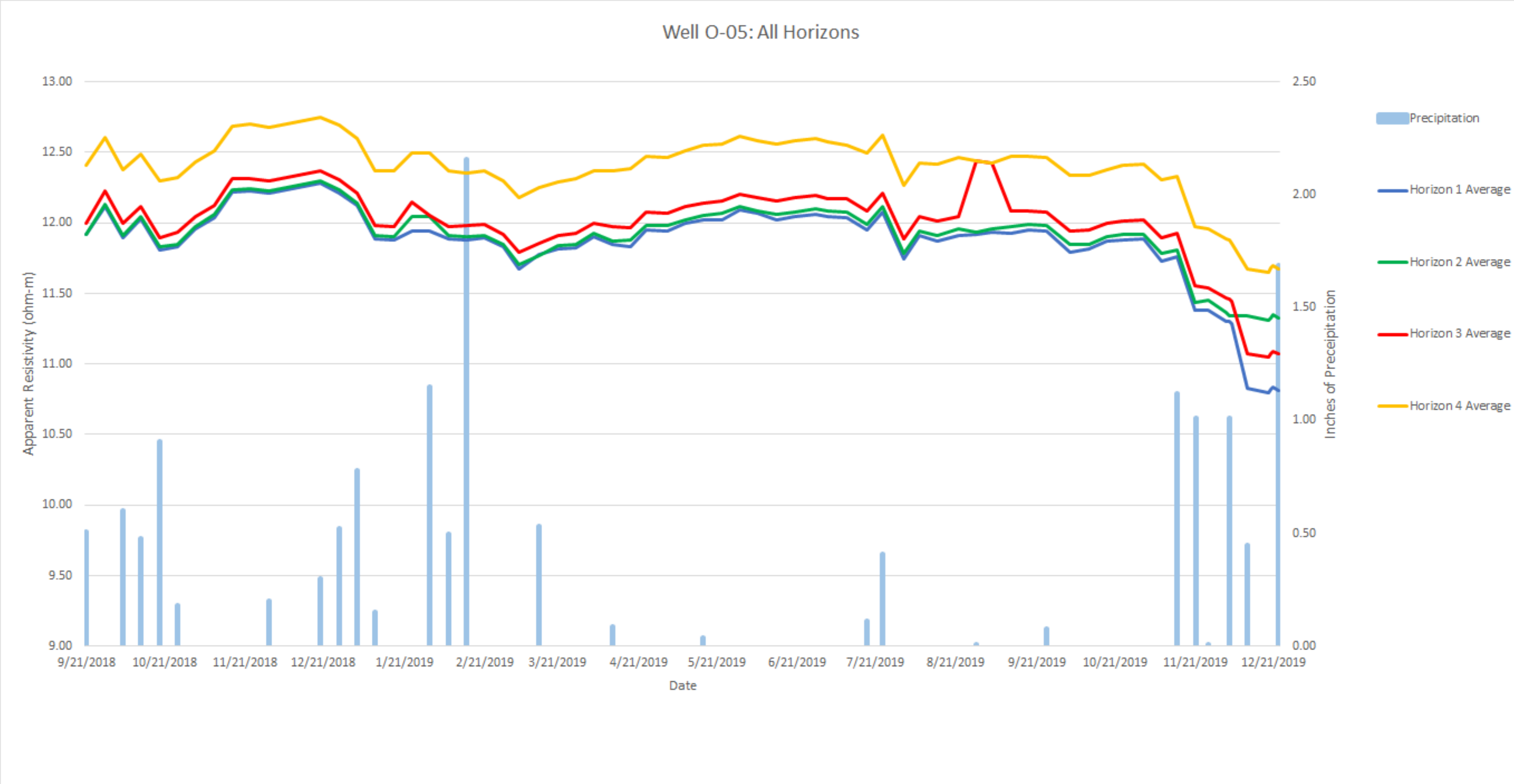
FIGURE 5



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OBSERVATION WELL O-05:
ALL HORIZONS

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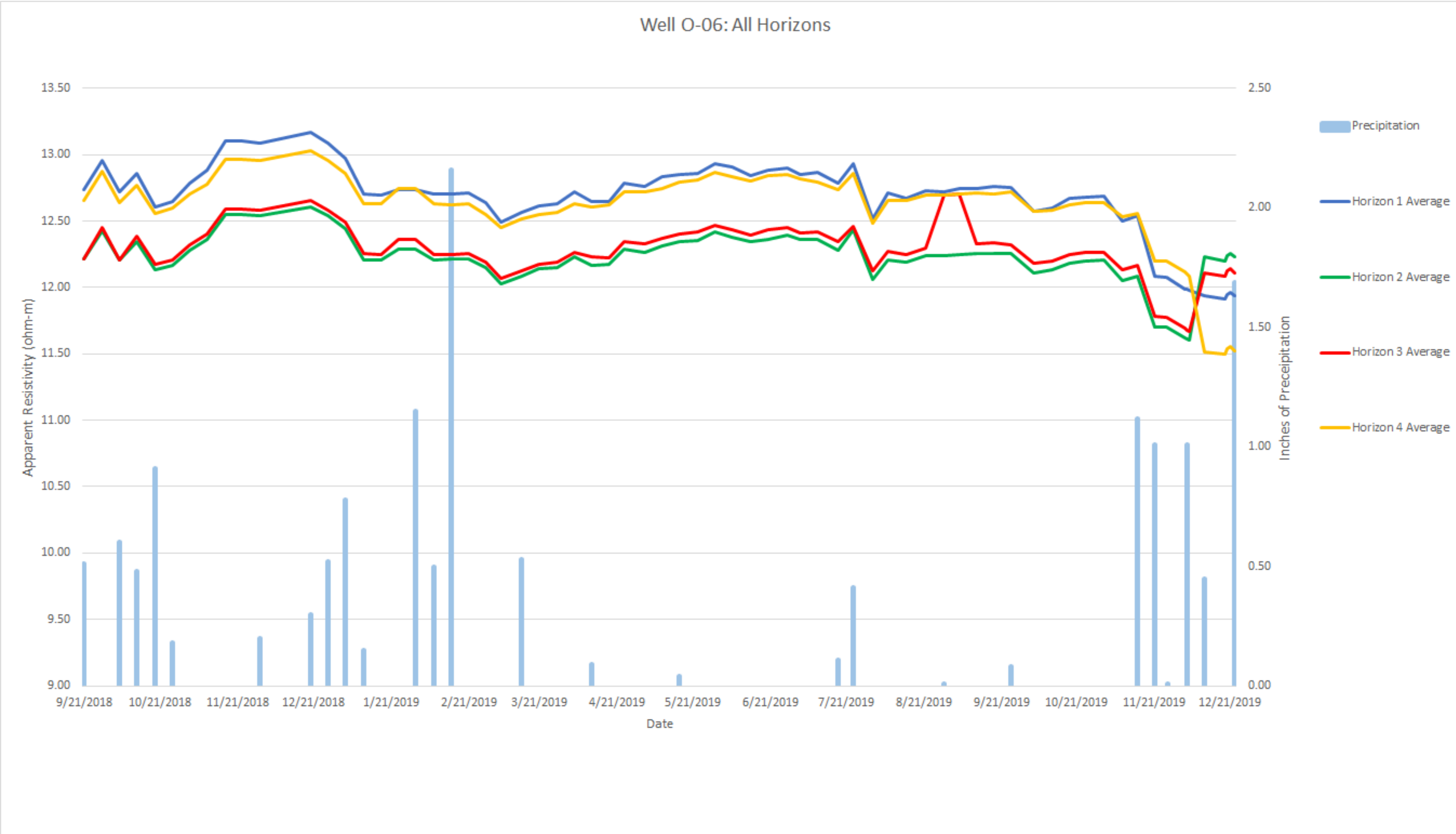
FIGURE 6



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OBSERVATION WELL O-06:
ALL HORIZONS

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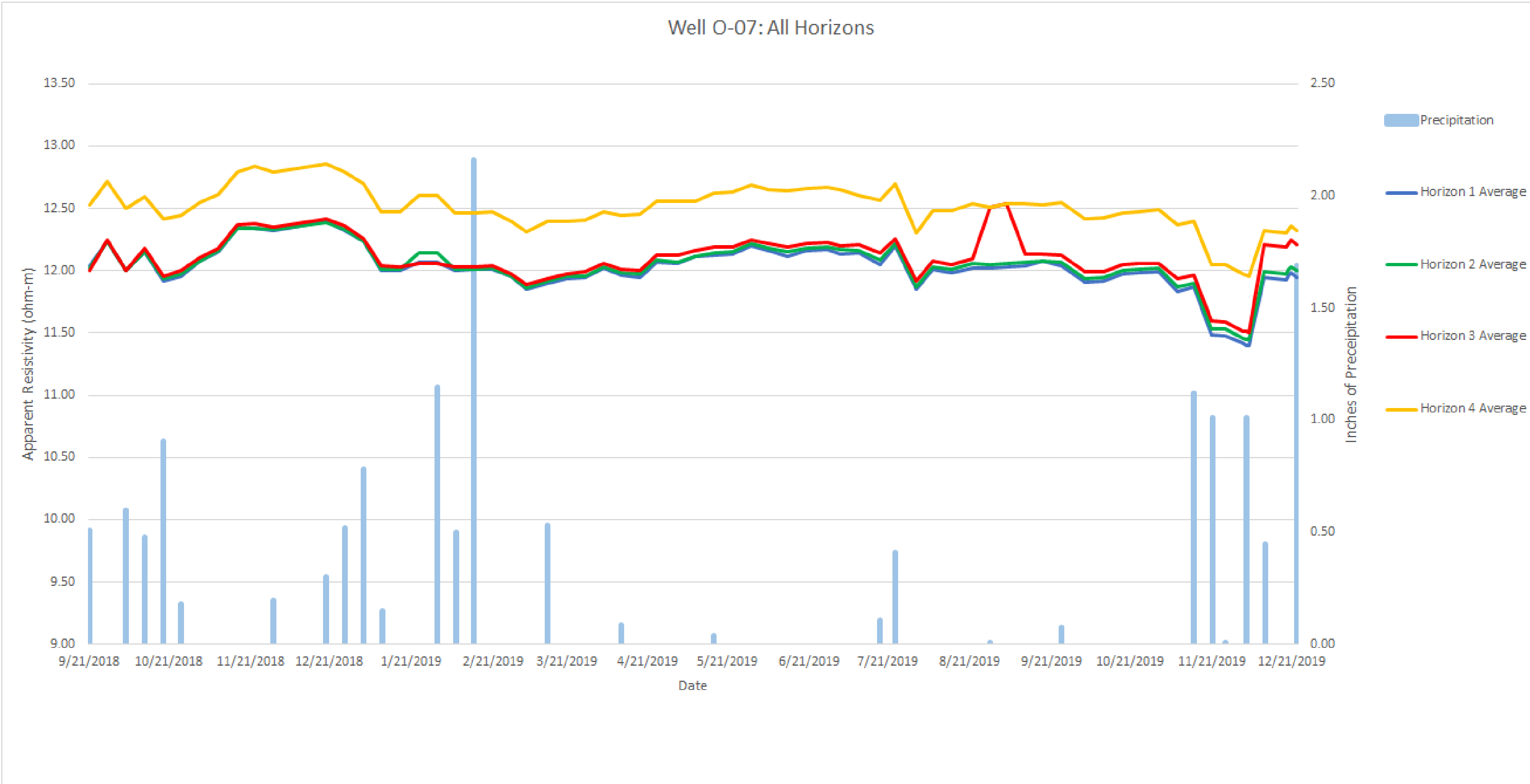
FIGURE 7



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OBSERVATION WELL O-07:
ALL HORIZONS

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FIGURE 8